OBSERVATIONS ON THE REPRODUCTIVE BIOLOGY OF *TORPEDO (TETRONARCE) MACKAYANA* (TORPEDINIDAE), FROM THE COAST OF SENEGAL (EASTERN TROPICAL ATLANTIC).

Christian CAPAPÉ, Laboratoire d'Ichtyologie, case 102, Université Montpellier II, Sciences et Techniques du Languedoc, 34095 Montpellier, cedex 5, FRANCE [capape@univ-montp2.fr], **Amadou Abdoulaye SECK**, Institut fondamental d'Afrique noire Cheikh Anta Diop, Musée de la Mer, Gorée, SÉNÉGAL, **Youssouph DIATTA & Mansor DIOP**, Département de Biologie animale, Faculté des Sciences et Techniques, Université Cheikh Anta Diop, BP 5005, Dakar, SÉNÉGAL.

RÉSUMÉ. Observations sur la reproduction de *Torpedo (Tetronarce) mackayana* (Torpedinidae), de la côte du Sénégal (Atlantique est tropical).

Des observations biologiques relatives à la torpille de Mackay, *Torpedo (Tetronarce) mackayana*, sont rapportées à partir de 78 spécimens capturés au large de la côte du Sénégal: taille de première maturité sexuelle des mâles et des femelles, diamètre et masse des ovocytes, période d'activité vitellogénétique, durée de la gestation, fécondités ovarienne et utérine. *T. (Tetronarce) mackayana* est une espèce lécithotrophe. L'espèce n'est pas prolifique et les deux types de fécondité sont en relation avec la taille des femelles. Parmi les embryons, les fœtus et les juvéniles, les mâles sont plus abondants que les femelles. On observe le phénomène inverse chez les adultes.

Key words: Torpedinidae - *Torpedo (Tetronarce) mackayana* - Senegal - ASE - Reproductive biology.

Two torpedinids belonging to the subgenus *Tetronarce* Gill, 1862 are recorded off the coast of Senegal (Cadenat, 1950; Séret and Opic, 1990): the electric ray, *Torpedo (Tetronarce) nobiliana* Bonaparte, 1835 and the Mackay's torpedo ray, *T. (Tetronarce) mackayana* Metzelaar, 1919. The former is rarely caught in the area, while the latter is sometimes landed, permitting us to present some data on its reproductive biology.

Material and methods

A total of 78 specimens, 35 males and 43 females, were observed. These specimens were caught by using gill-nets off the Cape Verde Peninsula and off the northern coast of Senegal, from the shallow coastal waters to 50 m depth, on sandy and/or muddy bottoms, rarely among macroalgae. They were collected at the fishing sites of Ouakam and Kayar, from 1994 to 1998.

In addition, 72 embryos and 15 fully-developed fetuses were examined. Embryos still had an umbilical stalk and an external vitellin vesicle. In fully- developed fetuses, this latter was completely reabsorbed into an internal vitellin vesicle, a scar marking the place of the umbilical stalk.

The specimens were measured to the nearest millimetre for total length (TL) following Stevens and McLoughlin (1991) and weighed to the nearest gramme. Measurements also included: clasper length (CL, mm) from the forward rim of the pelvic girdle to the tip of claspers according to Collenot (1969), the diameter and weight to the nearest decigramme for oocytes, eggs, embryos and fetuses. Developing oocytes were removed from the ovaries and ova, embryos and fetuses from the uteri, then counted, measured and weighed. Fetuses were also sexed as well as embryos when possible.

Males and females were studied separately. In males, the size at sexual maturity was determined by the regression of clasper length *versus* total length. According to Stevens and Lyle (1989), the claspers of juvenile males are short and flexible. Males are considered to be mature when claspers are elongated and calcified.

To emphasize embryonic development and the role of the mother during gestation, a chemical balance of development (CBD) was considered. CBD is based on the mean dry weight of fertilized eggs and fully-developed fetuses. CBD can be computed as the mean dry weight of fully-developed fetuses divided by the mean dry weight of fertilized eggs. Water content of 50% in ova and 75% in recently pups can be taken as standard values, based on analyses in *Scyliorhinus canicula*, by Mellinger and Wrisez (1989). CBD is a tentative estimate in order to show the role of the female during gestation.

Results

Size at sexual maturity

Males. The CL to TL regression shows that two growth phases can be considered (Fig. 1). The first phase included 16 juveniles between 180

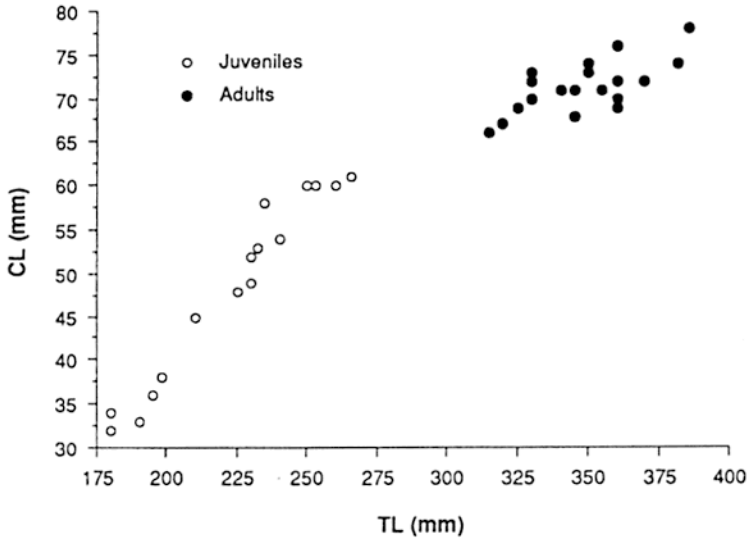

Fig. 1. Clasper-length (CL) *versus* total length (TL) regression in male *Torpedo (Tetronarce) mackayana*.

and 266 mm, whilst the second 19 adults between 315 and 382 mm.

Females. In females, two classes of specimens were distinguished by the condition of the ovaries and the morphology of their reproductive tracts. Juveniles had oocytes of microscopic size and membranous oviducts. Their nidamental glands were inconspicuous. Adults possessed two functional ovaries with yellow yolked oocytes. The two uteri were fully developed and functional. Nidamental glands were slightly rounded and visible.

Fifteen juveniles and 28 adults were observed. The juveniles were from 160 to 280 mm TL and the adults from 350 to 500 mm TL. Among the adults, 14 exhibited developing or ripe oocytes, two had not vitellogenetic activity and their uteri were empty, while 12 were gravid. Among the gravid specimens, the smallest was 350 mm TL, two had fertilised ova, eight bore embryos and a single female bore fully-developed fetuses. All gravid females exhibited degenerating oocytes.

Size and weight at birth

The 15 fully-developed fetuses ranged from 92 to 96 mm (mean: 95.55 mm; standard-deviation: 1.45), they weighed from 20.1 to 22.5 g (mean: 20.64 g; standard-deviation: 0.61).

Reproduction

T. (Tetronarce) mackayana possesses two ovaries and two uteri, both being functional. The ovaries produced cohorts of similar sized oocytes. One of these cohorts developed into ripe oocytes, the other degenerated. The diameter of 29 ripe oocytes prior to be ovulated ranged from 26 to 32 mm (mean: 28.73 mm; standard-deviation: 1.71). Fourteen adult females exhibited a phase of vitellogenic activity with growing or ripe oocytes in their ovaries, while their uteri were in a resting phase. In contrast, the ovaries of gravid females were in a quiescent phase (Table I). Capture of adult females with fertilized, non encapsuled eggs occurred in May and June. Females with developing embryos were caught in June and July and a gravid female with fully developed fetuses in August. The embryos were sexed over 25 mm TL approximately. Two females captured in September had their ovaries in a resting phase while their uteri were empty and distended. They probably were post-parturition.

Chemical balance of development (CBD)

The 29 ripe oocytes ranged from 8.5 to 9.6 g (mean: 9.21 g; standard-deviation: 0.37), while that of 32 fertilized eggs ranged from 8.3 to 8.9 g (mean: 8.59 g; standard-deviation: 0.15). The average weight of 15 fully-developed fetuses

ranged from 20.1 to 22.5 g (mean: 20.64 g; standard-deviation: 0.61). The estimated CBD for *T. (Tetronarce) mackayana* is 1.20.

Fecundity

Developing and ripe oocytes ready to be ovulated were more numerous in the right ovary than in the left one. This was also true for uteri contents. Ovarian fecundity (OF) based on the number of ripe oocytes ranged from 10 to 18 (mean: 12.57; standard-deviation: 2.62). Uterine fecundity (UF) ranged from 6 to 15 (mean: 10.66; standard-deviation: 1.15). OF and UF are correlated with the size of the females. The relationships are: OF = 0.047 TL - 7.069; r = 0.855 with n = 14 and UF = 0.053 TL - 10.819 with n = 12.

Sex ratio

Among embryos and fetuses, males were more abundant than females (Table II). Among the juveniles, the males were slightly more numerous than the females. In contrast, in adults, females were more numerous than males.

Discussion

Females *T. (Tetronarce) mackayana* mature at a larger size than males, 350 *versus* 315 mm respectively. These data agree with Capapé and Desoutter (1980) who estimated size at first maturity occurring between 350 and 360 mm in females and between 320 and 330 mm in males. Females were generally larger than males. The largest female was 500 mm TL and weighed 2010 g. The largest male was 382 mm TL and weighed 1255 g. This is another example of size dimorphism among torpedinids, where females are sexually mature at a larger size than males and reach a larger maximal size (Mellinger, 1981, 1989).

Fully-developed fetuses observed in an adult female allow us to state that birth occurred between 92 and 96 mm, and between 20.1 and 20.5 g.

Ovulation probably occurred in May-June and parturition in August or September. Consequently, gestation could last 4 or 5 months and the reproductive cycle one year. This was also observed in *T. (Torpedo) torpedo* from the

Table I. Reproductive cycle of female *Torpedo (Tetronarce) mackayana*. Condition of ovaries and uteri during gestation.

Month of catch	Number of observed females	Females size range (TL, mm)	Ovarian activity	Oocytes condition	Oocytes diameter range (mm)	Uteri content	Uteri content length range (TL, mm)
Mar.	4	350-380	vitellogenesis	developing	12-14	resting	-
Apr.	8	400-500	vitellogenesis	developing	18-22	resting	-
May	2	410-480	vitellogenesis	ripe	26-32	resting	-
May	1	355	resting	-	-	eggs	-
Jun.	1	360	resting	-	-	eggs	-
Jun.	2	366-440	resting	-	-	embryos	12-17
Jun.	3	390-450	resting	-	-	embryos	21-27
Jul.	2	350-400	resting	-	-	embryos	65-68
Jul.	2	340-415	resting	-	-	embryos	82-84
Aug.	1	420	resting	-	-	fetuses	92-96
Sep.	2	355-445	resting	-	-	-	-

Table II. *Torpedo (Tetronarce) mackayana* sex ratio for each category of specimens and for the total sample.

Category		Number of males	Number of females	Ratio (M:F)
In utero	Embryos and fetuses	38	29	1.31:1
	Juveniles	16	15	1.06: 1
Free living specimens	Adults	19	28	0.68:1
	Total	35	43	0.86:1
	Total	73	72	1.01:1

Tunisian coasts (Quignard and Capapé, 1974). In general, gestation and reproductive cycle are reported to be longer in torpedinids (Capapé, 1979; Mellinger, 1981, 1989).

Vitellogenesis proceeds in parallel with gestation in numerous elasmobranchs (Dodd, 1983; Mellinger, 1989). In torpedinids of the subgenus *Torpedo* (*sensu* Fraser-Brünner, 1949), the oocyte growth is blocked during gestation, until parturition (Quignard and Capapé, 1974; Mellinger, 1981, 1989). This phenomenon was also observed in *T. (Tetronarce) mackayana*. Among all these torpedinids, another similarity is the lack of an egg capsule. In *T. (Tetronarce) mackayana* uteri, the fertilised eggs remain free. A similar phenomenon was also described in squalids, such as *Centroscymnus* spp. from off the coast of Japan (Yano and Tanaka, 1988), *Centroscyllium fabricii* from off Greenland (Yano, 1995), and *Oxynotus centrina* from off Mediterranean locales and the coast of Senegal (Capapé *et al*., 1999).

Following the theoretical values given by Mellinger and Wrisez (1989), the CBD of c. 1.23 obtained for *T. (Tetronarce) mackayana* is a relative low value, close to that reported in *Oxynotus centrina* (1.36; Capapé *et al*., 1999). However, if using the data of Ranzi (1932), i.e., 48% of water in ova and 83% in fetuses, CBD should be 0.8 for *T. (Torpedo) torpedo* from Naples and 1.50 for *T. (Tetronarce) mackayana* from Senegal. These data indicate that Mackay's Torpedo ray is lecithotrophic according to Wourms (1977, 1981) and Wourms *et al*. (1988). In the torpedinids, the role of the female during embryonic growth is not important.

In an adult female of *T. (Tetronarce) mackayana* Capapé and Desoutter (1980) have found 10 ripe oocytes (from 23 to 26 mm in diameter). Our data show that the two types of fecundity have low values and that they slowly increase with size. Ovarian fecundity is higher than uterine fecundity probably because some oocytes were not ovulated and degenerated. Moreover, some females can loose their brood when captured.

T. (Tetronarce) mackayana appears to be relatively more prolific than *T. (Tetronarce) nobiliana*. Among torpedinids, there is a relationship between fecundity and species size as summarised in table II.

Among the embryos and the fetuses, males were more numerous than females. This phenomenon was also observed in *T. (Torpedo) marmorata* from the Baye of Biscaye (Mellinger, 1981) and in *T. (Torpedo) torpedo* from the Tunisian coasts (Quignard and Capapé, 1974). The other changes of sex ratio among juveniles and adults are due to sampling rather than to a high rate of mortality according to the sex.

Acknowledgements. The authors are grateful to the fishermen from the fishing sites of Ouakam and Kayar (Senegal) who provide them with material and to the three referees for their useful and helpful comments on the manuscript.

REFERENCES

BIGELOW H.B. & W.C. SCHROEDER, 1953. Fishes of the western north Atlantic. Sawfishes, Guitarfishes, Skates and Rays, Chimaeroids. *Mem. Sears Found. Mar. Res., New Haven*, 1(2): 1-588.

CADENAT J., 1950. Poissons de mer du Sénégal. *Init. afr.*, 3: 1-345.

Table II. Relation between fecundity and species size (TL, mm) in some torpedinids.

Species	Fecundity		Size at birth (mm)	Size	Authors
	Ovarian	Uterine			
Torpedo (Torpedo) torpedo	1-15	1-9	80-97	200-410	Quignard and Capapé, 1974
T. (Torpedo) marmorata	3-15	2-13	110-145	390-500	Capapé, 1979
T. (Torpedo) fuscomaculata	-	5	?	250	Capapé and Farrugio, 1986
T. (Torpedo) bauchotae	16-24	?	?	590-790	Capapé, unpubl. data
T. (Tetronarce) nobiliana	24-66	> 60	> 159	1000-1800 ?	Bigelow and Schroeder, 1953; Stehmann and Bürkell, 1984
T. (Tetronarce) mackayana	10-18	6-15	92-96	350-500	This paper

CAPAPÉ C., 1979. La torpille marbrée, *Torpedo marmorata* Risso, 1810 (Pisces, Rajiformes) des côtes tunisiennes : nouvelles données sur l'écologie et la biologie de la reproduction de l'espèce, avec une comparaison entre les populations méditerranéennes et atlantiques. *Ann. Sci. nat., Zool.*, Paris, 13éme série, 1: 79-97.

CAPAPÉ C. & M. DESOUTTER, 1980. Nouvelles descriptions de *Torpedo (Tetronarce) nobiliana* Bonaparte, 1835 et de *Torpedo (Tetronarce) mackayana* Metzelaar, 1919. *Bull. Mus. natl. Hist. nat.*, Paris, 4ème sér., 2, section A, n° 1: 325-342.

CAPAPÉ C. & H. FARRUGIO, 1986. Nouvelle description de *Torpedo (Torpedo) fuscomaculata* Peters, 1855 (Pisces, Torpedinidae). *Bull. Inst. natl. scient. techn. Océanogr. Pêche Salammbô*, 13: 55-70.

CAPAPÉ C., SECK A.A. & J.P. QUIGNARD, 1999. Observations on the reproductive biology of the angular rough shark, *Oxynotus centrina* (Oxynotidae). *Cybium*, 23(3): 259-271.

COLLENOT G., 1969. Étude biométrique de la croissance relative des ptérygopodes chez la petite roussette *Scyliorhinus canicula* L. *Cah. Biol. mar.*, 10: 309-323.

DODD J.M., 1983. Reproduction in cartilaginous fishes (Chondrichthyes). *In:* Fish Physiology (Hoar W.S., Randall D.J. & E.M. Donaldson, eds), pp. 31-95. New York: Academic Press.

MELLINGER J., 1971. Croissance et reproduction de la torpille (*Torpedo marmorata*). I. Introduction. Écologie. Croissance générale et dimorphisme sexuel. Cycle. Fertilité. *Bull. Biol. Fr. Belg.*, 105: 165-218.

MELLINGER J., 1981. Biologie et physiologie du développement, de la croissance et de la reproduction des torpilles : un aperçu des recherches depuis 1965. *Arch. Inst. Pasteur Tunis*, 58: 441-463.

MELLINGER J., 1989. Reproduction et développement des Chondrichthyens. *Océanis*, 15: 283-303.

MELLINGER J. & J. WRISEZ, 1989. Biologie et physiologie comparée de deux sélaciens ovipares, les roussettes *Scyliorhinus canicula* et *Scyliorhinus stellaris*. Évolution de la matière sèche, de l'eau et des ions (Cl^-, Na^+, K^+) dans le vitellus de *S. canicula* au cours du développement. *Bull. Soc. Zool. Fr.*, 114: 51-62.

QUIGNARD J.P. & C. CAPAPÉ, 1974. Recherches sur la biologie d'un Sélacien du golfe de Tunis, *Torpedo torpedo* Linné, 1758 (Écologie, sexualité, reproduction). *Bull. Inst. Océanogr. Pêche Salammbô*, 3(1-4): 99-129.

RANZI S., 1932. Le basi fisio-morfologiche dello sviluppo embrionale dei Selaci I. *Pubbl. Stn zool. Napoli*, 12(2): 209-290.

SÉRET B. & P. OPIC, 1990. Poissons de Mer de l'Ouest africain tropical. 416 p. Init. Doc., ORSTOM, Paris, 49.

STEHMANN M. & D.L. BÜRKEL, 1984. Torpedinidae. *In:* Fishes of the North-Eastern Atlantic and the Mediterranean (FNAM), Vol. I (Whitehead P.J.P., Bauchot M.-L., Hureau J.-C., Nielsen J. & E. Tortonese, eds), pp. 159-162. Paris: Unesco.

STEVENS J.D. & J.M. LYLE, 1989. Biology of three hammerhead sharks (*Eusphyra blochii*, *Sphyrna mokarran* and *S. lewini*) from northern Australia. *Aust. J. Mar. Freshw. Res.*, 40: 129-146.

STEVENS J.D. & K.J. McLOUGHLIN, 1991. Distribution, size and sex composition, reproductive biology and diet of sharks from northern Australia. *Aust. J. Mar. Freshw. Res.*, 42: 151-199.

WOURMS J.P., 1977. Reproduction and development in chondrychthyan fishes. *Am. Zool.*, 17: 379-410.

WOURMS J.P., 1981. Viviparity: The maternal-fetal relationship in fishes. *Am. Zool.*, 21: 57-67.

WOURMS J.P., GROOVE J.P. & J. LOMBARDI, 1988. The maternal-embryonic relationship in viviparous fishes. *In:* Fish Physiology, Vol. XI (Hoar W.S. & D.J. Randall, eds), pp. 1-134. London: Academic Press.

YANO K., 1995. Reproductive biology of the black dogfish, *Centroscyllium fabricii*, collected from waters off western Greenland. *J. Mar. Biol. Ass. U.K.*, 75: 285-310.

YANO K. & S. TANAKA, 1988. Size at maturity, reproductive cycle, fecundity, and depth segregation of the deep sea squaloid sharks *Centroscymnus owstoni* and *C. squamulosus*. *Nippon Suisan Gakkaishi*, 54: 167-174.

Reçu le 25.10.1999.
Accepté pour publication le 13.11.2000.